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KEEPING PACE WITH GLOBALISATION INNOVATION CAPABILITY IN KOREA'S TELECOMMUNICATIONS EQUIPMENT INDUSTRY

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This paper is part of a larger UNU-INTECH research project (2000-31-161-00) analysing the innovation capability of the telecommunications equipment industry in four developing countries namely Brazil, China, India and Korea. I am grateful to UNU-INTECH for giving me the opportunity to work on this project. Excellent logistical support in Korea was provided by the International Co-operation Agency for Korea IT in general and Wonbae Son in particular. Research assistance provided by Sean Lim is gratefully acknowledged too. I am also thankful to Eveline in de Braek for her kind help with some of the data tables. Thanks are also due to Narayan Ramachandran for making available a number of useful documents on the Asian telecommunications industry. The anonymous referee at the Centre made a number of useful suggestions and comments, some of which are incorporated in the paper. But none of them are to be implicated for any errors or shortcomings that may still remain in the paper.

ABSTRACT

Korea is one of the four from the developing world to have built up substantial innovation capability in the design and manufacture of state-of-the-art telecommunications equipments. The paper undertakes a detailed review of this innovation capability and analyses its precise status during the time when the Korean economy was subject to a serious financial crisis. The paper maps out the sectoral system for innovation in the telecommunications equipment industry and measures the innovation capability in terms of a set of three separate indicators. The ensuing analysis shows that the country has built up substantial innovation capability in not just fixed telephony but also in mobile communication technologies. There has been some passage of this capability from the public research laboratory to private sector manufacturing firms. The Korean state has continued to support the public laboratory through a variety of financial grants and public technology procurement. However these traditional instruments of support are no longer valid in newer technologies such as mobile telephony. The innovation system has nevertheless achieved considerable sophistication that it is in a position to keep pace with changes in the technology frontier

Key words: Innovation Capability, Korea, Telecommunications, Digital Switching systems, CDMA Mobile Telephony.

JEL Classification: L630, O310, O320, O380.

Introduction

South Korea is recognised as a world leader in mobile content and its application and its outstanding success has been in the field of broadband technology is now well recognised (International Telecommunications Union 2003, Lee and Choudrie, 2003). Korean development experience in general and her success in a number of areas of high technologies is now very well known. Her success in creating and using new technologies for the developmental needs of the country has now become an integral part of the so called Korean model of development. While her success in general has attracted considerable amount of interest in the development economics community, case studies on specific areas of technologies in which she has done exceedingly well is less easy to come by. The focus of the current study is on one such area of high technology development where the country has now emerged as one of the serious global players. This is the case of the telecommunications equipment industry. Like many other areas of high technology development, the telecommunications equipment industry in Korea has emerged out of a judicious mixture of well thought out government initiatives coupled with legendary private sector dynamism. The industry is now an integral and important component of the country's information and communications technology (ICT) industry. See Table 1.

Table 1: The place of telecommunications equipment industry in Korea's ICT Industry, 1997-2002 (Domestic production in trillions of Korean Won)

Year	Telecommunications		Other IT equipments		Electronic components	Software	Total ICT
	Equipments	Services	Information Equipments	Broadcasting Equipments			
1991	2.02	5.5	2.43	0.19	7.79	0.25	18.17
1992	2.53	6.61	2.47	0.23	9.14	0.72	21.71
1993	2.63	7.43	2.99	0.33	11.32	0.96	25.66
1994	3.06	8.49	4.03	0.28	17.36	1.17	34.39
1995	4.63	11.14	6.33	1.38	26.28	1.67	51.44
1996	8.92	14.81	6.39	1.58	25.08	2.67	59.44
1997	13.8	17.00	9.8	0.6	30.9	3.5	75.5
1998	14.2	17.90	10.7	0.7	39.9	4.7	88.1
1999	12.0	21.60	15.7	0.9	50.3	6.5	114.9
2000	21.76	28.60	20.9	1.6	60.9	10.7	145.2
2001	24.5	32.90	18.3	1.6	57.8	15.4	150.5
2002	28.1	37.90	24.0	3.4	77.9	17.8	189.1

Source: Ministry of Information and Communication (2002), p. 8.

Although its share has tended to come down, the telecommunications industry (both equipments and services) account for very nearly a third of the total output of the ICT industry.

The basic objective of the paper is to analyse the record of the country with its endeavour towards maintaining its innovation capability in the telecommunications equipment industry. Of specific interest is the mechanisms employed by the Korean state to cope with the challenges paused by two important changes in the external environment namely (a) privatisation of telecommunications services industry and the opening up of the equipment industry to foreign participation; and (b) the Korean financial crisis of 1997 and the consequent need to restructure the sectoral system of innovation of the industry.

The study is structured into seven sections. The first section elucidates on the conceptual framework underlying the study and undertakes a review of past studies done on the theme. The unique features of the telecommunications industry in the country are brought out in the second section. Applying the sectoral system of innovation perspective, the third section maps out the innovation system of the country by focusing specially on two of the more important components, namely the government research institute and the manufacturing firms. The fourth section measures the innovation capability of the sector in terms of three separate indicators by focusing on achievements in both fixed and mobile telephony. The fifth section presents the case of one successful innovation capability in fixed telephony and another one in mobile telephony equipments. The sixth one discusses the more proximate determinants of this capability. The seventh one concludes.

I. Past literature and conceptual Framework

Past literature

The Korean telecommunications sector has attracted a limited number of systematic inquiries. One of the earliest works in this area is by Goransson (1993). He chronologically outlines the development of technological capability in the telecommunications equipment industry. The history of the industry could be traced to 1962, when the manufacture of electromechanical strowger systems were initiated. However the production of public switching systems of the digital electronic variety commenced only in 1980. There are four main actors or agents in the innovation system for the telecommunications industry: the Ministry of communication which charts the overall policy framework towards this sector, the domestic equipment manufacturers, the government research institute (GRI) that is charged with the responsibility of developing the necessary technologies (namely the Electronics and Telecommunications Research Institute) and lastly the public sector service provider (namely Korea Telecommunications). An important and positive aspect of the innovation system is the strong interaction between the GRI, industry and universities facilitated by government supported R&D and a policy designed to assist and stimulate local industry in building capacity to innovate. Industry's motivation for participating in joint R&D and to accelerate own development efforts, has been further stimulated by at least three factors: (i) the public technology procurement of the main service provider, Korea Telecom, which gave preferential treatment to locally developed equipments, thereby assuring a ready market; (ii) government provided subsidies for the performance of R&D; and (iii) sufficient supply of well trained scientists and engineers. Goransson's study highlights a very interesting aspect of Korea's development of innovation capability in digital switching systems, namely that the government initially resorted to the import of disembodied technology through the licensing mechanism, obtained the technology and then encouraged the firms to indegenise and development local capability through the careful crafting of an efficient and credible sectoral system of innovation: the extent of indegenisation ranged from 3 to 70 per cent in matter of five years (1984-1988).

The subsequent research on a similar theme by Mytelka (1999) also recounts this rapid build up of innovation capability in digital switching systems. An important additional point brought out by the Mytelka study is that the introduction of domestic technology (as in the case of Brazil) led to a rapid decrease in the price of digital switching systems: the average price of digital switching systems which had peaked to US $ 491 per line in 1989 has subsequently came down to about US $ 237 per line by 1993 (Mytelka, 1999, p. 143). This significant reduction in the average prices leads her to suggest that ‘‘simply having an alternative is a powerful bargaining tool for government in its negotiations with the foreign technology supplier while the threat of open competitions from a comparable switch cannot be taken lightly. By putting firms on guard, it provides a stimulus to cost reductions that make competitive pricing possible if the threat becomes a reality''.

Both the above studies thus focused on the earlier phase of the Korean innovation system (the period up to the early 1990s) when the country very successfully managed to emerge from being just an importer of digital switching systems to being able to design and manufacture these systems on a sustained basis and this being a credible alternative to foreign technology.

The next major phase in Korea's acquisition of innovation capability is its development and commercialisation of Code Division Multiple Access (CDMA) technology in mobile telephony. Korea is credited as the as first country to have commercialized this technology originally developed by the US based telecom company, Qualcomm[1]. Most of the

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1 Although the Korean ETRI together with its manufacturers is widely accepted as the first one to commercialise this technology, the original designs were done by Qualcomm. It is a bit surprising to note that Qualcomm's website does not even make a mention of this For instance it states the following,, " QUALCOMM first introduced CDMA in 1989, three months after the Cellular Telecommunications Industry Association (CTIA) had endorsed another digital technology called Time Division Multiple Access. As CDMA's effectiveness was proven in a series of field demonstrations throughout the world, many key service providers and manufacturers signed agreements with QUALCOMM in support of CDMA technology validation activities. In 1993, the Telecommunications Industry Association (TIA) adopted the cellular standard IS-95 based on CDMA, which stands for Interim Standard 95. It became the foundation for a whole new generation of CDMA-based cellular systems. In 1995, CDMA was selected as a standard for Personal Communications Services. (PCS). Commercially introduced in 1995, CDMA quickly became one of the world's fastest-growing wireless technologies. In 1999, the International Telecommunications Union selected CDMA as the primary technology for third-generation (3G) wireless systems. Many leading wireless operators are now building or upgrading to 3G CDMA networks to provide more capacity for voice traffic, along with high-speed data capabilities". See http://www.qualcomm.com/about/history.html (accessed on August 5, 2004)

research done on this experience is, however, available only in Korean language[2]. One of the important pieces in this area is the recent study by Lee and Hahn (2003). The study analyses the evolution of the innovation system in the Korean mobile telecommunication industry. It discusses how the roles of and interactions between players in the system, such as the government, government-sponsored research institutes, and domestic and foreign firms, have changed along the evolution of the technology in the industry.

Thus our survey, albeit brief, shows that the Korean government has been rather successful in crafting a sectoral system of innovation. Central to this system are two agents, namely, the public laboratory and the manufacturing enterprises. Korea has successfully managed to enlist the support and involvement of its manufacturing enterprises for carrying out innovation related activities. With the Korean financial crisis of 1997 and the consequent need to restructure and open up its economy to foreign competition, this innovation system is believed to have come under some strain. In the following we will examine in detail whether this indeed is the case.

Conceptual framework

The study employs the familiar sectoral system of innovation of the Malerba (2004) variety. According to him, ‘‘a sectoral system of innovation is composed by the set of heterogeneous agents carrying out market and non market interactions for the generation, adoption and use of new and established technologies and for the creation, production and use of new and established products that pertain to a sector’’. In this framework, the innovation in a sector is considered to be affected by three groups of variables: knowledge and technologies; actors and

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2 See the works of Wichin Song in Korean. These could be found at: http://www.stepi.re.kr/main01/homepage/frame.asp?id=songwc. (Accessed on January 28 2005)

networks; and institutions. This approach of Malerba has been applied to mobile telecommunications by Edquist (2003).

II. Features of the Korean telecommunications sector

The section is organised as follows. First of all I outline the current structure of the telecommunications services industry. This is followed by four important dimensions of the sector: (i) growth of investment and capacity; (ii) technological improvements in the network; (iii) phenomenal growth of mobile telephony and the near saturation of fixed telephony; and (iv) structural changes in the telecom industry with the distribution of services accounting for the dominant share of the industry.

Korea's telecommunications sector has undergone many changes over the 1990s.

(i) Growth of investment and capacity

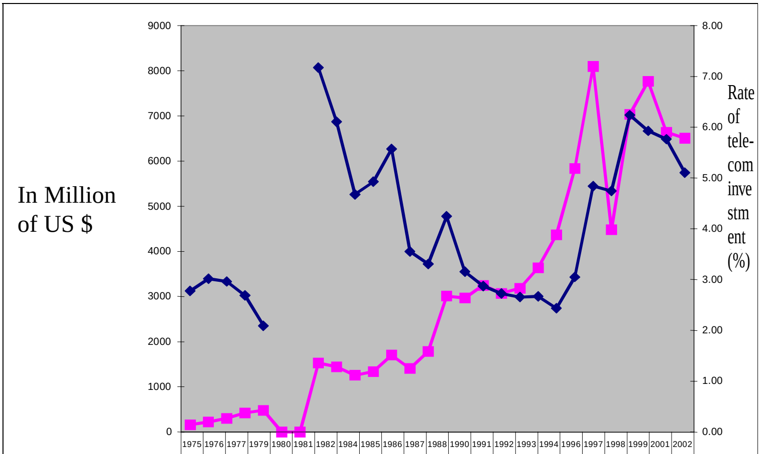
Although the absolute level of investments in telecommunications has increased almost continuously, the relative rate of telecom investments has actually declined until the mid 1990s and thereafter it has picked up (Figure 1). This increase in the rate of investment roughly coincides with the phase of privatisation of telecom services[3].

3 The Ministry of Information & Communication advanced by two years the concession schedule Korea submitted to the WTO/GBT in February 1997. As a result, foreign entities are now able to own up to 49% of Korea's basic telecommunications service companies (except for Korea Telecom) and hold management control over the companies as major shareholders. The ceiling on foreign ownership of Korea Telecom (KT) was raised from 20% to 33% on September 1, 1998, ahead of the original commitment for the year 2001. The limit on individual foreign ownership also was raised from 7% to 15% in October 1998. The government sold some of its shares in KT by issuing depository of receipts (DR) in overseas capital markets, reducing its stake in KT from 71.2% to 58.99%. The government plans to further reduce it share to 33.4% by 2000. KT was declared a fully privatised company on August 20, 2002

Table 2: Structure of the Telecommunications distribution sector in Korea: December 31, 2003 (Number of service providers in each category)

	Fixed Line			Mobile			Trunked Radio System		Wireless Paging		Wireless Data Communication and Broanband Wireless Internet
	Local	Long distance	Interna tional	Cellular	PCS	IMT 2000	Nation wide	Local District	Nation wide	Local district	
1991	1	1	2	1	-	-			1		
1991-95	1	2	2	2	-	-			11		
1995-98	2	3	3	2	3	-			13		
2003	2	4	4	1	2	3	1	5	1	3	3 + 1

Source: OECD (2000); International Co-operation Agency for IT Korea (2003)



	1975	1976	1977	1979	1980	1981	1982	1984	1985	1986	1987	1988	1990	1991	1992	1993	1994	1996	1997	1998	1999	2001	2002
Annual Telecom Investments	159	221	300	479	0	0	1527	1258	1340	1705	1407	1783	2968	3249	3069	3184	3634	5840	8096	4479	7038	6642	6507
Rate of Tecom Investments	2.78	3.02	2.96	2.09			7.17	4.68	4.93	5.57	3.55	3.31	3.16	2.87	2.73	2.66	2.67	3.05	4.84	4.74	6.24	5.77	5.10

Figure 1: Trends in Telecom Investment

Source: International Telecommunications Union (2003)

(ii) Technological improvements in the network

In order to deliver new services such as video conferencing and video on demand, as well as provide more bandwidth for the increasing volume of traditional data, the communications industry introduced a technology that provided a common format for services with different bandwidth requirements. This technology is Asynchronous Transfer Mode (ATM). ATM is a cell-switching and multiplexing technology that combines the benefits of circuit switching (guaranteed capacity and constant transmission delay) with those of packet switching (flexibility and efficiency for intermittent traffic). It provides scalable bandwidth from a few megabits per second (Mbps) to many gigabits per second (Gbps). Because of its asynchronous nature, ATM is more efficient than synchronous technologies, such as time-division multiplexing (TDM). The growth of the Internet, need for broadband access and content, e-commerce and more are spurring the need for a reliable, efficient transport system - ATM Technology. For voice, video, data and images together, the next generation network depends on ATM. Korea has been in the forefront of developing its internet accessibility and infrastructure. Towards this direction it has started producing ATM switches in 1996 and there have been significant increases in its production in 2001 and 2002 (Table 3). Currently it stands at almost over three quarters of public switching production in the country.

Table 3: Relative share of ATM Switches in total Public Switching Output, 1990-2002 (Millions of US $)

	Public Switching	ATM Switching	Share of ATM Switching
1990	552.74		
1991	584.79		
1992	579.93		
1993	503.78		
1994	485.38		
1995	446.75		
1996	345.47	17.10	4.95
1997	663.57	28.33	4.27
1998	748.88	17.12	2.29
1999	569.67	18.86	3.31
2000	585.68	46.15	7.88
2001	478.78	389.57	81.37
2002	244.31	181.85	74.43

Source: Korea Association of Information and Telecommunication (2003)

(iii) Phenomenal growth of mobile telephony: In the world as a whole mobile telephony has over taken the fixed one. In Korea the change over to wireless telephones took place much earlier in 2000 (Figure 2). There are essentially three service providers (Table 4).

Table 4: Structure of the Korean Mobile Telecom Service Industry, 2002-2003

Service provider	Sales Revenue (100 million Won)		Number of subscribers (1000 subscribers)	
	2002	2003	2002	2003
1. SK Telecom	86,340 (53.2)	95,202(56.6)	17,219(53.3)	18,313(54.5)
2. KTF	53,200 (32.8)	50763 (30.2)	10,332 (31.9)	10,441(31.1)
3. LG Telecom	22,374(13.8)	22,274 (13.2)	4790(14.8)	4836 (14.4)

Note: Figures in parentheses indicate percentage share of the total
Source: ICA for Korea IT (2004), p.30

Mobile communication in Korea is composed of two submarkets: mobile phone services (98.7 per cent) which in turn include Personal Communication Services (PCS in the 1.8 Ghz bandwidth) and cellular phone services (800 Mhz bandwidth), TRS, wireless data communication and paging services. Diffusion rate of mobile services, currently (c2003), works out to 68 per cent of the total population. It must, however, be stated that up to the early 1990s, low cost paging service and high cost car phone services accounted for all of the wireless services available in the country. But with the introduction of CDM mobile communication technology in 1996, the earlier wireless services and especially paging has lost ground. Over the period 1996 through 2002, CDMA technology itself has undergone three major metamorphisms, namely IS-95 A/B in 1996, CDMA 2000-1x in 2000 through CDMA 2001-x EV-DO in 2002.

An interesting dimension of the Korean mobile scene is the use of mobile phones for accessing the internet. Mobile internet service commenced in the 1990s with SMS and duplex SMS. Currently commercial services such as WAP and ME have been introduced. Starting with 2002 newer m-business services such as Global Positioning System (GPS) management service for logistics, transportation and postal service industry, Sales Force Automation (SFA)/Field Force Automation (FFA)

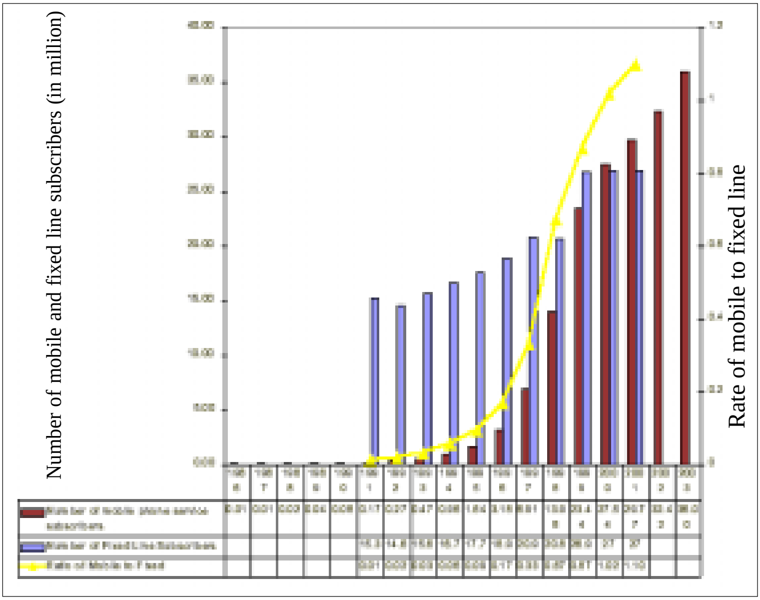
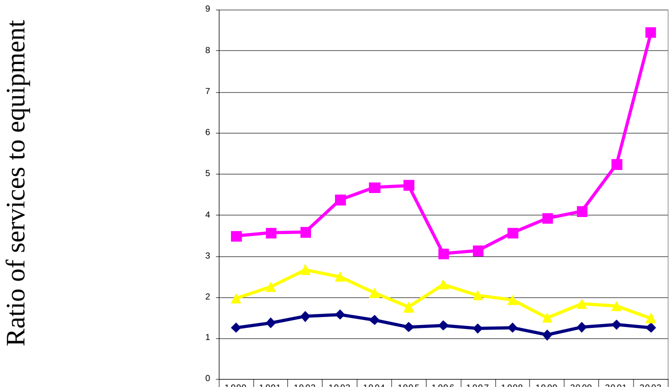


Figure 2:Ratio of mobile to fixed line subscribers in Korea, 1991-2003

Source: Ministry of Information and Communication(2001)and OECD (2003)

for finance, manufacturing and distribution industry, mobile office services such as group and remote control and measurement services for network industries such as electricity, gas and water have been introduced. Thus it is seen the mobile communication industry is evolving into a very sophisticated service industry offering a range of new mobile services to the industry.

(iv) Distribution of telecom services Vs manufacturing of telecom equipment: Unlike in Brazil and India, the size of the telecom equipment industry is as big as the distribution of services segment (Figure 3). The equipment industry is able to maintain its parity with the services segment due essentially to the growth of wireless communications equipments (read as mobile communication).



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ratio of telecom services to equipment industry	1.2583	1.3832	1.534	1.5898	1.4537	1.2828	1.3202	1.2396	1.2554	1.0861	1.2727	1.3326	1.2704
Ratio of services to wired equipment	3.49	3.57	3.59	4.37	4.68	4.73	3.07	3.14	3.57	3.93	4.10	5.24	8.45
Ratio of services to wireless equipment	1.97	2.26	2.68	2.50	2.11	1.76	2.32	2.05	1.94	1.50	1.85	1.79	1.50

Figure 3: Relative growth of telecommunications equipment Vs Services, 1990-2002

Source: Korea Association of Information and Telecommunication (2003)

III. Innovation system for telecom equipment industry

The Korean government has put in place a detailed and elaborate system of innovation for facilitating innovative activity in this industry. The present system of innovation is mapped out in Figure 4. The innovation system has six main constituents. Central to the innovation system are the research system and the manufacturers. As has been noted before the strongest point about the innovation system has been the close interaction that exist between the governments, the research system the private sector manufacturers and the service providers. This point can be amplified by examining two major innovative achievements of the system, namely (a) development of the TDX family of digital switching systems; and (b) the development and commercialization of the Code Division Multiple Access (CDMA) technology in mobile telephony. Before I proceed to discussing these two cases of successful innovation, it is necessary to spend some time discussing two of the more important actors, the Electronics and Telecommunications Research Institute (ETRI) and the domestic equipment manufacturers.

(i) Electronics and Telecommunications Research Institute (ETRI): was established in 1976 and it is the largest among the 27 GRIs in the country. Administratively speaking it is currently placed under the Korea Research Council for Industrial Science and Technology.

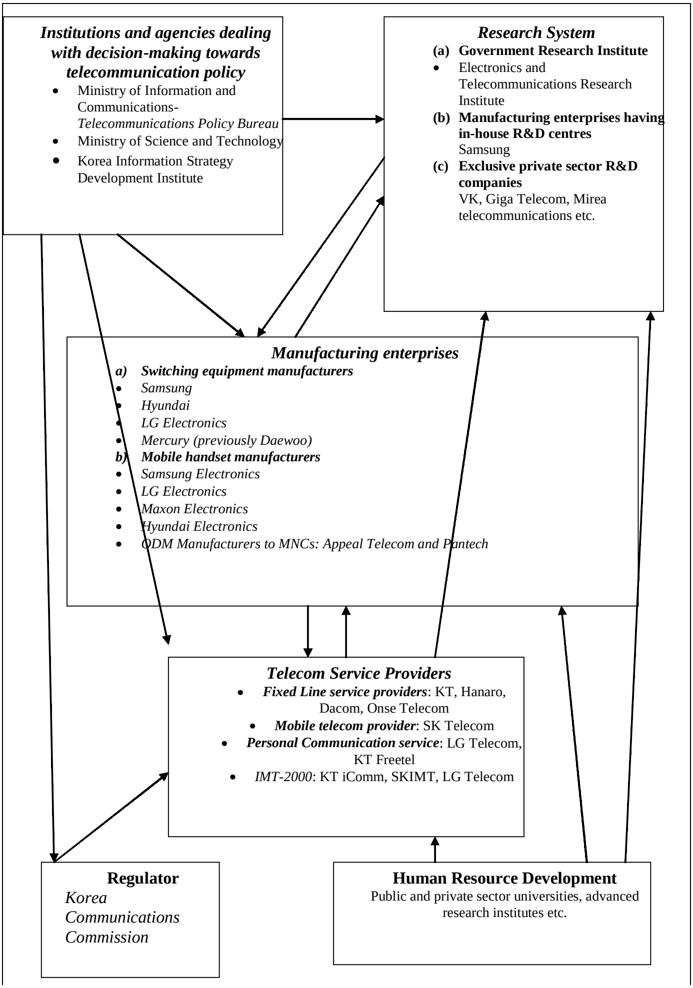


Figure 4: Current structure (c2004) of Korea's Telecommunications Equipment System of Innovation

Source: Own compilation

The history of ETRI is outlined in Table 5.

Table 5: Major milestones in the history of ETRI (Korea)

Year	Major milestone
1976	Two separate research institutes KECRI, an affiliate of KIST (MOST) and KIET (MOCI) was established
1977	Merging the above two, KTRI was established by the Ministry of Information and Communication (MIC)
1980	Affiliation of KTRI changed from the MIC to MOST
1981	KETRI established by MOST
1985	A new laboratory called ETRI was established by the MOST consolidating KTRI and KETRI
1992	Affiliation of ETRI was changed from MOST to MIC
1996	SERI incorporated into ETRI as an affiliate
1998	*Restructured into 4 technology laboratories and 3 divisions*
1999	Affiliation was changed to KOCI of the Office of the Prime Minister
2000	National Security Research Institute established as an affiliate of ETRI
2001	*Restructured into 6 technology laboratories, 2 divisions and 1 affiliated organization*
2002	*Further restructured into 6 technology laboratories, 3 divisions and 1 affiliated organisation*

Source: Electronics and Telecommunications Research Institute (2003), p. 3.

It is interesting to note that the laboratory has undergone three rounds of restructuring since the Korean financial crisis of 1997[4]. In the following I analyse the performance of this laboratory in terms of the following: (a) Human resource; (b) Source of funding of its research activities; (c) Output of its R&D activities (restricted to telecommunications research) in terms of patents granted, papers published and technologies actually transferred to the industry. Of particular interest is to see whether the functioning of the laboratory was adversely affected by the Korean financial crisis of 1997 and especially when the lab had undergone three separate episodes of organizational restructuring. Given the paramount role played by the ETRI in Korea's telecommunications innovation system, the exercise is likely to lead us to practial policy conclusions.

(a) Human resource: The primary asset of any laboratory is the quality and quantity of its human resource and from this point ETRI has a very strong tradition of being able to attract to attract the best talent in the country. However with the growth of private sector R&D laboratories across Korea and given the higher financial incentives and career prospects offered by the private sector counterparts, there is a general feeling that ETRI has ceased to become a favourite destination for the best scientists and engineers in the country. However, contrary, to this popular impression the total employment and especially of the research staff have actually increased by nearly 3 per cent per annum (Table 6). The increase has been almost entirely contributed by increases in the

4 In fact the Korean government had in 1996 changed its research funding system in an effort to boost research efficiency and productivity. The new system, called the Project-Based System (PBS), replaced the lump-sum system. Instead funds were extended by means of research project contracts. Further in 1999, a new one on the creation, operation, and development of GRI was enacted. The law is supposed to have created a new system endowing GRIs with autonomy in operation, management, decision making, and organisation of GRI’s under the new law five research council’s were established.

research staff, a third of who have doctoral degrees and more than 60 per cent have post graduate degrees. Compared to both Brazil and Indian counterparts, ETRI is significantly more endowed with scientists and engineers.

(b) Source of funding: Changes in the reporting of income by the lab over time renders any interpretation of the source of funding a bit difficult (Table 7). Analysis of the source of income reveals two important points. Firstly, funds from government remains the most important source of income for the lab and in fact in the more recent periods it has emerged as the most important, accounting for almost 80 per cent of the total income of the lab. So the so called restructuring of the GRI's in Korea consequent to the financial crisis does not appear to have had any perceptible impact on the funding of ETRI: it has continued to enjoy

Table 6: Structure of employment in ETRI: 1997-2003
(Number of persons)

	1997	2003	Growth Rate (%)
Research staff	1290	1633	3.50
Technical staff	71	69	-0.48
Technicians	68	30	-21.11
Administrative staff	118	152	3.73
Total	1547	1884	2.98

Source: Electronics and Telecommunications Research Institute (1997 and 2003)

the confidence of the Korean government. However my discussions with researchers at ETRI revealed that much of this funding came in the form of short term funds for specific projects that had the potential of deriving some tangible output in the short-run and hence planning for long -term R&D projects became difficult since 1997. Secondly, although the total income has increased by 4.5 per cent per annum, the average income per employee has increased significantly lower at 1.34 per cent per annum. In other words increase in the total income is accounted for to a great extent increase in the total size of the laboratory.

Table 7: Source of funding of ETRI's Income: 1997-2003
(Hundred millions of Won)

	1997	Percentage share	2003	Percentage share	Growth rate (%)
Funds from government	242.96	8.45	3044	80.47	
R &D fund	1944.36	67.63			
Net government funding			110	2.91	
Funds from private sector			406	10.73	
Other income	687.55	23.92	158	4.18	
Transfers from previous year		65	1.72		
Total	2874.87	100	3783	100	4.51
Average income	1.86		2.01		1.34

Source: Electronics and Telecommunications Research Institute (1997 and 2003)

The above analysis thus confirms the proposition that despite the financial crisis and despite the demands that have been placed on the shoulders of the government by multilateral financial institutions in reducing its transfers to GRI's, the Korean government continues to the major source of income for ETRI.

ETRI is a multi technology laboratory. As its name suggests it focuses not only on telecommunications technologies but also on information technology in general. In the following I present some specific indicators regarding its R&D performance with respect to telecommunications technologies: first a list of major telecommunications technologies developed and commercialized by the lab is presented (Table 8) and this is followed by a quantification of the new market creation effect of these technologies (Table 9).

Table 8: Major R&D projects successfully completed in Telecommunications technologies by ETRI, 1976-2002

Year	Major telecommunications technology developed
1978	Development of 6.3 Mbps Optical Transmission System for 96 Voice Channel
1979	Development of 44.7 Mbps capacity Optical Transmission Equipment
1981	Development of a New-Type Public Telephone
1986	Beginning of the TDX-1 system
1989	Operated the first ISDN model system in Korea
1990	Development of the TDX-ISDN Switching system
1992	Development of the 155 Mbps grade synchronous optical transmission system
1993	Development of the 2.5 Gbps Grade Optical Transmission System
1994	Development of the CDMA mobile communication system
1995	Development of a 155 ZMbps Optical Communication Module
1995	Development of ATM switching system for very high speed test bed network
1996	• Commercialisation of CDMA digital mobile system • Development of World's first ATM multimedia switching chip (MCS)
1998	Development of ATM switching system
1999	Development of RF CMOS IC for cellular telephones.

Source: Electronics and Telecommunications Research Institute (2003)

It is thus seen that all the major telecommunications technologies were developed during the period up to 1999. This does not mean that the lab was not active in the post 1999 period. During this phase the lab has developed a number of electronics technologies and has continued to make further improvements in its ATM switch.

(c) New market creation effect: This is a cost-benefit analysis measure and it is computed by taking a ratio of the new market created by a specific technology to its total direct spent in creating that technology. The former variable is proxied by computing the total market created by the technology and this is composed of the domestic sales of that technology plus its exports sales. The latter variable is proxied by the total R&D investment in that project. A value greater than unity indicates that the benefits are more than the cost. The new market creation index for four of the important telecommunications technologies successfully developed by ETRI has been computed and this is presented in Table 9.

Table 9: Estimated new market effect of major telecommunications technologies developed by ETRI, 1976-2003
(in billions of Korean Won)

Type of technology	Period	Domestic supply	Export sales	Total sales	R&D investment	New Market Creation Effect
TDX	1978-1993	4470	522	4992	107	46.65
CDMA	1989-1996	34970	19070	54040	78	692.82
ATM Switching System	1992-2001	109	89	198	160	1.24
Optical trans-mission system	1993-2001	1910	12	1922	50	38.44

Source: Computed from data provided in Electronics and Telecommunications Research Institute (2003)

My analysis shows that new market creation effect is greater than unity for all the four technologies. It is not surprising that the figure for CDMA is the highest. For the lab as a whole, the average new market creation effect of all its technologies[5] successfully developed and commercialised is 1.44.

(ii) Domestic manufacturers[6]: The next most important component of the sectoral system of innovation is the domestic telecommunications manufacturers. As noted before, all the major R&D projects initiated by ETRI involved the participation of these dynamic manufacturers. There are four different types of manufacturers First is the three large domestic manufacturers (Table 10), namely Samsung, LG and Mercury which manufactures all three different types of telecommunications equipments such as switching, transmission and terminal equipments for both fixed and mobile communication. Second is a range of small and medium enterprises manufacturing essentially mobile handsets. Some of these are Own Design Manufacturing (ODM) for foreign MNCs. Third is a collection private R&D companies which take up contract research for both local and foreign companies. According to the ICA for Korea IT, there are more than 90 such private R&D companies. Finally is a set of electronic component manufacturers.

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5 In addition to telecommunications technologies ETRI has also successfully developed and transferred the following technologies namely high density semiconductors, optical transmission systems, TiCOM and in PCs. See Electronics and Telecommunications Research Institute (2003).

6 In working out the ideas contained in this sub section I have drawn from the information contained in Lee, Malik and Bidaud (2003) and on the basis of the field research at Korea during February 2004. Research assistance provided by Sean Lim is also gratefully acknowledged.

Table 10: Profile of the three large domestic telecommunications equipment manufacturers (c2004)

Name of manufacturer	Major focus area	Major strengths (Weakness)	Current business focus
Samsung Electronics	• Mobile infrastructure, including mobile phones (94 per cent) • Access technologies (3 per cent) • Optical transmission (1 per cent) • Switching (1 percent) • Others (1 percent)	CDMA systems; Metro Ethernet; strong marketing and distribution reach at home and overseas(NGN)	Driving metro ether net system
LG Electronics	• Mobile infrastructure, including mobile phones (90.2 per cent) • Access technologies (2.4 per cent) • Optical transmission (2.4 per cent) • Switching (3.4 percent) • Others (1.4 percent)	NGN; CDMA Systems (Transmission)	Dropped transmission division in 2003 having agreed to co-develop soft switch for Korea Telecom (KT)-NGN in 2002; No: 1 market share of access gateway to KT in 2002; consolidating Wireless in Local Loop system for export.

cont'd....

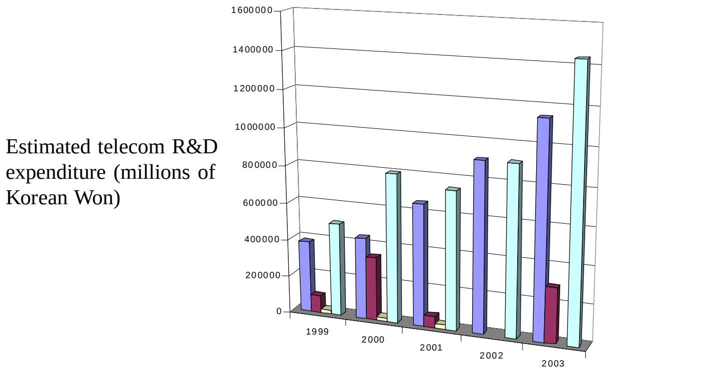
Name of manufacturer	Major focus area	Major strengths (Weakness)	Current business focus
Mercury (formerly known as Daewoo communi-cations)	Optical transmission (40 percent) Switching (35 percent) Others, including cable modems, PBX, digital STBs and so forth (25 per cent)	TDM switching; transmission systems(NGN)	Diversification into other telecom equipment product lines, breaking from voice network system.

Note: Historically speaking there was a fourth manufacturer, namely HanHwa Corporation. However it is no longer in the telecoms business.

Source: Lee, Malik and Bidaud (2003); Field research notes

It is thus seen that the two leading manufacturers both Samsung and LG are both focusing on mobile handsets and systems. Mercury[7] seems to be the only remaining major switching equipment manufacturer. It must also be noted that all the firms are multi technology corporations with telecommunications forming only part of the total sales of these companies. The only company, among the top three, that is an exclusive telecom manufacturer is Mercury. Based on the relative share of telecom products in total sales of the companies, I have derived an estimate of their R&D expenditure on telecommunications equipments (Figure 5).

7 It is a privately held company with investments from CVC Asia Pacific, Carlyle Asia Investment Advisors and PPM Ventures Asia. It has entered into strategic alliances with MNCs such as Alcatel and Nortel to address the booming broadband and 3G marketplace in Korea.



	1999	2000	2001	2002	2003
SEC	385735.7671	439119.7999	657276.2731	909827.925	1146154.658
LGE	92842.64	342803.04	61039.98		295798.35
Mercury	21667.88	17655.03	23746		
Total	500246.2871	799577.8699	742062.2531	909827.925	1441953.008

Figure 5: Estimated telecom R&D expenditures by leading Korean manufacturers, 1999-2001

Source: Own compilation based on field research notes.

Despite the limitations of the data, it is seen that the R&D investments have shown significant growth during the post crisis period. This is an interesting finding that the technology activities of the firms have not shown any tendency to shrink during the post crisis period. This is because a part of the crisis period (namely the 1998-2000) also coincided with the boom period in the telecoms industry. A still another reason is the competition from especially western MNCs and technology had become the main instrument of competition between the firms.

Thus, in the above, I have outlined the sectoral system of innovation and discussed the performance of two of the more important components of the system. The main point that emerges is the fact that Korea's innovation system for telecommunications equipment industry does not appear to have been adversely affected by the financial crisis which engulfed the country during this period. The government has continued to support the public laboratory, although it is feared that focus of some of its concerns were dictated by short-term concerns. The introduction of ATM switching and the continued progress with respect to mobile technology are important outcomes of this phase.

IV. Innovation capability in the telecommunications equipment industry

Following Mani (2002 and 2003), the term innovation capability in a particular technology is defined as the ability to conceptualise, design and manufacture state-of-the-art telecommunications equipments and also to keep pace with changes in the world frontier in that technology. Transliterating this definition of innovation capability into measurable indicators is attempted by employing three separate but related indicators. They are: (a) two separate indices of innovation capability which measures innovation capability of both fixed and cellular telecom equipments respectively; (b) market share of domestically developed switches in the total Korean network; and (c) an analysis of patents granted to Korean inventors in four US patent technology classes, namely in 370, 375, 379 and 455.

(a) Index of innovation capability: There are two such indices: Index of innovation capability in fixed telephone equipment, IICFT and Index of innovation capability in mobile telephone equipments, IICMT. They are computed as follows:

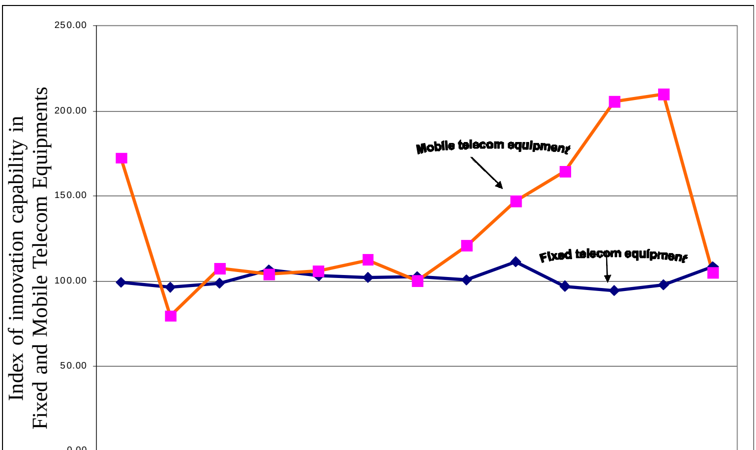
$$IICFT = \frac{\text{Domestic production of public switching equipments} * 100}{\text{Domestic production +Imports-Exports of public switching equipments}} \quad \text{-----(1)}$$

$$IICMT = \frac{\text{Domestic production of wireless telecom terminals} * 100}{\text{Domestic production+ Imports-Exports of wireless telecom terminals}} \quad \text{--------(2)}$$

Where wireless telecom terminals is composed of cellular phones + PCS+ IMT-2000 terminal+ TRS terminal.

(1) and (2) are computed for the period 1990-2002 based on the relevant data provided in Korea Association of Information and

Telecommunication (2003) and are presented in Figure 6. A value greater than 100 means that the country has innovation capability, although it must be added that since the index is based on production data, problems in domestic production may bring down the value of the index for that year, but this may not mean that the innovation capability is decreasing. It is important that one should be using the index to form an informed opinion about the over all movements in innovation capability over a period of time. In other words the index is not robust enough to track year to year movements in innovation capability.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
IICFT	99.38	96.58	98.65	106.76	103.26	102.37	102.81	100.79	111.18	97.21	94.71	97.89	108.38
IICMT	172.53	79.73	107.34	103.92	106.05	112.64	100.24	120.82	147.29	164.51	205.67	209.96	105.12

Figure 6: Index of innovation capability in fixed and mobile telecom equipments, 1990-2002

Source: Korea Association of Information and Telecommunication (2003)

It is seen that Korea has innovation capability in both fixed and mobile telecom equipment although its capability in mobile equipments appear to more strong than in fixed telephones. The successful implementation of both the TDX digital technology in fixed telephones and CDMA technology in mobile telephones are clearly reflected in the upward movements in both the indices.

(b) Market share in the network: Due essentially to availability of data the exercise here is restricted to fixed line telecom equipments (Table 11). The analysis shows that over three quarters of the network is composed of domestically designed and manufactured switches. In fact roughly half of the switches are of TDX family of switches designed by ETRI in collaboration with the four domestic manufacturers. This shows that even after the deregulation and privatisation of the service segment domestically designed switches continue hold sway. In fact the Korean manufacturers have the design and manufacturing capability in a number of state-of-the-art circuit and packet switching equipments (Table 12).

Table 11: Market share of domestically designed and manufactured switches in Korea Telecoms Network

(As on December 31, 2003)

Type of switch used by Korea Telecom (Manufacturer)	Installed capacity (in number of lines)
1. AXE10 (A 180) (Ercisson)	866,922
2. AXE10 (A 340) (Ericsson)	1,001,742
3. 5ESS (Lucent)	4785,180
A. Total foreign designed switching equipments (1+2+3)	**6653844 (24.44)**
4. TDX-1A (Samsung, LG, Daewoo, Hanhwa)	866,140
5. TDX-1B (Samsung, LG, Daewoo, Hanhwa)	4,265,546
6. TDX- 10 (10A) (Samsung, LG, Daewoo, Hanhwa)	5,840,421
7. TDX100 (Samsung, LG, Daewoo, Hanhwa)	4,600,010
8. S-1240 (Samsung)	1,771,100
9. SDX-200 (Samsung)	1,396,688
10. STAREX-TX1A (LG)	740,160
11. HDX-2000 (Hyundai)	576,000
12. DTS-4000 (Daewoo)	511,200
B. Total domestically designed switches (4+……+12)	**20567265 (75.56)**
Total switching equipments installed (A+B)	**27221109**

Note: Figures in parentheses indicate percentage share of total

Source: ICA for Korea IT (2004)

(c) Patenting performance of Korean telecom equipment manufacturers

Korean institutions, primarily, Samsung and ETRI has been particularly active in patenting in four areas directly connected with telecommunications technologies, namely US patent technology classes 370, 375, 379 and 455 (Table 13). It is seen that there has been a significant acceleration in patenting since 1998. Although the patents secured in year't' is the result of research done in 't-1' period, it is interesting to note that there has been no deceleration in the number of patents secured by Korean institutions in the US since the period of globalization[8]. In terms of the number of patents in these four classes, Korea compares very favourably with three European countries such like France, Germany and Sweden.

Thus my analysis, based on these three separate indicators confirms the view that Korea has built up considerable innovation capability in both fixed and mobile communications and is also able to keep pace with changes in the world frontier in these specific technologies. The government has continued to support and nurture the main component of the innovation system, namely the ETRI. The laboratory has been able to forge close and effective collaborations with leading private sector firms and the user, Korea Telecom too has participated in the R&D projects leading to its success.

I now present two cases where such a sectoral system of innovation was in working. The two cases are (a) the case of digital switching systems in fixed telephony of the 1980s; and (b) the case of CDMA in mobile telephony of the 1990s.

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8 The Korean economy has become increasingly integrated with rest of the world since 1998. So the period of globalisation, as far as Korea is concerned, is the period since 1998.

Table 12: Types of telecom switching equipments currently (c 2004) designed and manufactured by Korean telecom equipment manufacturers

Manu-facturer	Type of Switch	Name	
LG	ATM Core/	CellBit 500x ATM	: ATM Multiservices Edge Switching System
		STAREX-ATM	: General Purpose switch, support a wide range of
	ATM Access	Cell Gate 600 L	: High speed access concentrator that connect voice
		Cell Gate 600 M	: Multi-service access concentrator that provides
	Public	STAREX-TX1	: The STAREX-TX1 switching system supports local calls, long distance calls, ISDN services
		STAREX-TD	: Designed for cities and rural areas The system can be easily modified to meet the service.
		STAREX-IMS	: Switching system equipped with private as well as
		SMX-10	: High-speed packet switch designed to meet the complex requirements of SS7 networks and enable
	Next Generation Network	VintoP-2000	: VoDSL gaeway, The VintoP-2000 uses V5.2 as the
		AIG-240	: Aggregated IAD & Gateway
Samsug	Broadband Network	Ace MAP^{TM}	: AceMAP^{TM} is Samsung's solution to the goal of a single network for voice, data, and broadband.
	Public	SDX-200	: Switching solution for mobile telecommunication
	Next Generation	Softswitch	: The Softswitch, an intelligent component in the VoP network, is a forward-looking, next generation telecommunication
Mercury	Public	TDX-100	: Digital Switching System, developed based on international standard digital switching hierarchy
Han Hwa	Telecommunication equipment discontinued in 2002-03		

Source: Own compilation based on field research notes.

Table 13: Patenting performance of South Korea Inventors in the US for Telecommunications technology classes, 1990-2001 (Number of patents granted)

	370 Multiplex communication	375 Pulse of digital communications	379 Telephone communications	455 Telecomm-unications
1990	0	0	4	2
1991	4	5	9	3
1992	1	4	9	3
1993	3	8	8	8
1994	3	12	5	8
1995	3	19	4	4
1996	20	45	7	7
1997	19	43	6	5
1998	36	80	46	18
1999	46	77	64	45
2000	53	76	28	58
2001	63	89	11	76

Source: US PTO

V. Case studies of successful innovation capability

(i) Case of a successful fixed telephony technology- the case of digital switching systems [9]

The rationale for the digital switching system project more popularly known as the TDX (Time-Division Exchange)[10] project could

9 This write up is largely based on the discussions and the notes provided by the ETRI scientist, Byung-Sun Lee. See also Lee, Byung-Sun (1999). The usual disclaimer holds good.

10 The TDX family of digital switching systems consisted essentially of three main types of switches: TDX 1A used in local and tandem based on Assembly language with a capacity of 10, 240 subscriber lines, a termination capacity of 2040 trunks and Busy Hour Call Attempt (BHCA) of 100, 000; TDX 1B also used as local/ tandem based on C, Assembly language with a capacity of 22,528 lines, a termination capacity of 3840 trunks, and a BHCA of 220, 000; TDX-10 based on CHILL, c languages used in local/tandem/toll with a capacity of 100, 000 lines, a termination of 60, 000 trunks and 1, 200, 000 BHCA

be traced to the end of the third five year development plan (1972-1976), when the teledensity in the country was just 7.7 direct exchange lines per 100 people and a subscriber had to wait for more than a year to get a telephone connection in her/his premises after applying for it in the first place. The black market premium for a new telephone connection was as high as US $ 3000 per connection (almost similar to the situation prevailing in Brazil). The situation was contributed by the fact that the country relied almost exclusively on costly imported telecom switches from abroad and the country did not have a telecommunications manufacturing equipment industry and there was no domestic R&D programmes for the telecommunications industry. This state of affairs gave rise to a strong desire on the part of the Korean government to acquire both research and manufacturing capabilities and it manifested itself in the form of the TDX switching systems project at the newly created ETRI. In the following I discuss the following dimensions of this unique R&D project which in my view is a perfect example of what a tightly knit system of innovation can achieve. They are: (a) development history of the project (Table 14); (b) organization and funding; and its (c) economic effects in terms of import substitution and other spillovers to the Korean economy.

Thus the project has a development history of nearly 20 years during which time considerable improvements were made in the basic design reflecting the changes in the technology frontier.

Organisation and funding: The most unique aspect of the project was its organisation and funding. Although the term national system of innovation is used in the literature on economics of technological change, it is very often used in a loose fashion. However in the case of the R&D project for TDX exchange, one can easily detect a national system of innovation. At the heart of the project was ETRI which was responsible for the development and control of major parts of the system in terms of high level design and system integration. ETRI was assisted by a host of

Table 14: Development history of the TDX R&D project at ETRI, 1976-1997

Year	Major achievement
1976	TDTF (Telecommunication Development Task Force) decided to invest in the development of electronic switching system
1978	ETRI developed proprietary switching system
1982	TDX-IX system was installed in Yongin (500) lines
1984	TDX-1 system was developed
1986	• TDX-1 systems started services in four districts· • Korea became the 10th country in the world develop an electronic switching system
1987	TDX-1A system was developed (10, 000 lines)
1989	TDX- 1B system was developed (20, 000 lines), which has ISDN basic and supplementary services
1990	200 ISDN lines were built between Seoul and Taejon
1991	• ISDN service was extended to 500 subs in three cities • TDX-10 system was developed (100,000 LINES), and a commercial field testing was begun
1992	• 5 million TDX lines • TDX-10 system started commercial PSTN services
1995	TDX 10 system started IDSN and packet services
1997	10 million TDX lines

Lee (1999), pp. 8-9.

public universities and other GRIs in terms of basic research for the project. The basic technology was then transferred to four of the domestic electronics manufacturers namely Samsung, LG, Daewoo and Hanhwa:

in fact the total manufacture of the equipments was equally divided between these four (Table 15). Subsequently the manufacturers were able to design on their own upgraded versions of the switch and were even able to export these systems to a number of foreign countries. This point will be further elaborated with quantitative data. The manufacturers were specifically involved in low level design of the parts and in block implementation. The main consumer, Korea Telecom (KT) was responsible for programme management by providing the user requirement, conducting the specified qualification tests and in ultimately commercializing the technology.

Table 15: Production of TDX Switching Equipments by Korean Manufacturers, 1985-1996

(thousands of lines)

Year	SEC	LGE	Daewoo	Hanhwa	Total domestic production
1985	6	6	6	6	24
1986	47	47	47	48	189
1987	15	16	19	156	206
1988	41	43	49	208	341
1989	105	118	118	151	492
1990	283	340	300	410	1,333
1991	408	392	411	455	1,666
1992	371	339	335	310	1,355
1993	337	375	379	381	1,472
1994	246	215	155	152	768
1995	175	168	210	141	694
1996	221	267	184	159	831
Total	2,255	2,326	2,213	2,577	9,371

Source: Unpublished data from ETRI.

Most importantly, KT provided the entire funds that were required for the project. This is thus an excellent example of demand-driven public research in which all the components of the sectoral system of innovation have had a serious role to play. Figure 7 maps out this sectoral system of innovation.

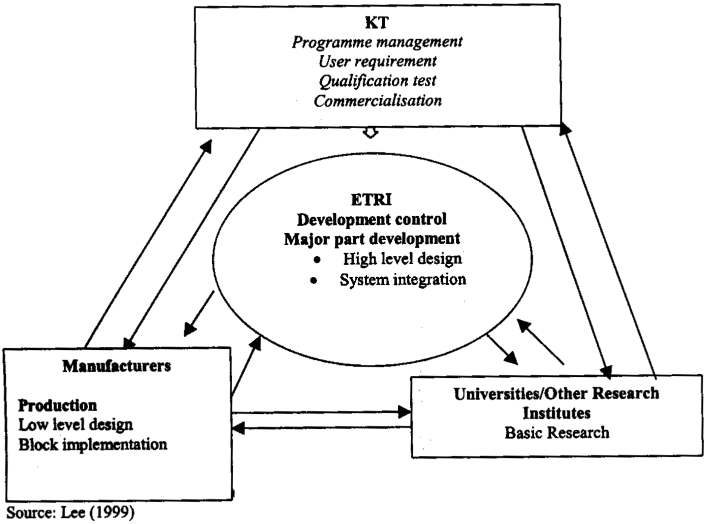

Figure 7: Sectoral system of innovation for TDX exchange equipments (1976-1997)

Source: Lee (1999)

Although difficult to quantify, the total R&D cost of the TDX project works out to US $ 213.9 million ranging from US $ 13.7 million in the case of TDX-10A to US $ 142.7 million in the case of TDX-10.

Economic effects of the TDX project:

I had earlier (see Table 9 above) the project had resulted in a large market creation effect in the sense that total domestic and foreign sales of the equipment far exceeded the total R&D investment. The ratio of domestic production to imports has steadily been increasing and has exceeded unity since 1991, reaching a peak in 1993 has fallen since then, but remaining greater than unity all along. (Figure 8).

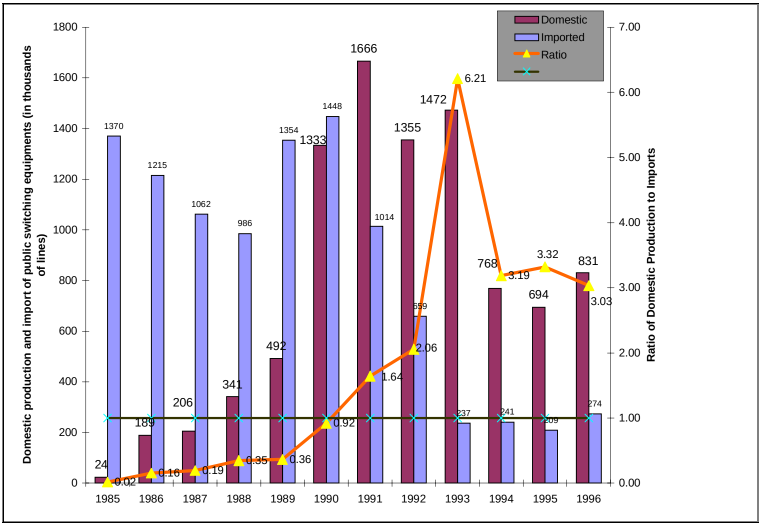

Figure 8: Extent of import substitution in telecom switching equipments in Korea, 1985-1996

Source: Lee (1999)

This substitution of imports with domestic production has enabled Korea not only to increase its tele density rather significantly, but has also managed to prepare the country for the internet revolution. Further, the four TDX manufacturers have exported over 3.7 million TDX lines worth, US$ 709 million to 23 countries during the 7 years since 1991 and over 500 patents were secured by ETRI emanating from this project.

In short although the project has been a great success, there are two issues that may dampen the enthusiasm for this success. First is the share of imported components in these domestically designed switches [11]. No precise estimates of these are available[12] . Second, the original design for this switch was based on a design imported from the Swedish telecom giant, Ericsson. It is not immediately clear whether Korea had to pay a recurring royalty linked to sale of these exchanges. This is an important issue that needs to be verified as can be seen from our subsequent discussion of the case of the CDMA mobile telephone technology payment of royalty for the original design imported from abroad is now proving to be a costly affair for the implementation of that technology.

(ii) Case of a successful mobile telephony technology- the development of CDMA: Almost exactly the same year ETRI was in the process of completing its development of TDX 1A exchange equipment it embarked on the development of mobile communication technology. This was a major strategic direction for the lab and for its acquisition of innovation capability as Korea is the only country from the developing world to have foreseen the possibility of phenomenal future growth in mobile communications. Deciding on CDMA as the mobile technology was indeed fraught with difficulty as a number of studies show that foreseeing which wireless technology is the most profitable one is almost next to impossible (Fransman, 2002 and 2003, Birchler, Smyth, Martinez and Baker, 2003). In mobile communications much of the world had opted for the Global System for Mobile Communications standard (GSM)[13]. See Table 16. But CDMA is growing fast too.

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11 Mytelka (1999) too had expressed this view in her earlier study.

12 During my interviews at ETRI I was informed that towards the initial stages it used to be 50 per cent, subsequently this was brought down to 12 per cent and then to 5 per cent.

13 GSM is an open, non-proprietary system that is constantly evolving. One of its great strengths is the international roaming capability. This gives consumers seamless and same standardised same number contactability in more than 170 countries. GSM satellite roaming has extended service access to areas where terrestrial coverage is not available.For a detailed overview of this technology see Scourias, John, http://ccnga.uwaterloo.ca/~jscouria/GSM/gsmreport.html#1 (accessed on January 28 2005)

Table 16: Distribution of World mobile subscribers according to technology, 2000-2004 (in millions)

	2000 (December 31)	2004 (March 31)
GSM	455.1	1046.8
CDMA	82.2	199.1
W-CDMA	-	4.3
PDC	50.8	62.4
US TDMA	65.2	111.2
Total digital subscribers	653.3	1440.0
Total analogue subscribers	68	16.5
Total wireless subscribers		1456.5

Source: http://www.gsmworld.com/news/statistics/index.shtml (accessed on January 28 2005)

After intense debate[14] in the early 1990s, Korean authorities eschewed known time division multiple access (TDMA) technologies and set off down the relatively unknown CDMA road. Under the auspices of the Korean Electronics and Telecommunications Research Institute, local vendors such as LGIC, Samsung, Hyundai and Maxon began to develop systems based on Qualcomm's CDMA common air interface imported from the United States. TDMA systems such as GSM and digital AMPS (D-AMPS) were perceived to be maturing technologies that were approaching their performance limits rather than future technologies with greater possibilities.

Based on the accumulated experience of the TDX project, the CDMA project too adopted the same organizational form by having a tightly knot sectoral system of innovation. Following the usual practice, I first present a history of the project followed by its organisation and funding and then its economic effects to the Korean economy at large.

14 However much of this debate is in the Korean language.

Table 17: Development history of CDMA technology, 1989-1996

Jan	1989	: Initiation of digital cellular system development by ETRI
Aug	1991	: Joint Development Agreement (JDA) with Qualcomm, Inc.
Dec	1992	: Roaming Test System (RTS) by Qualcomm delivered, installed and field-tested in Taejon, Korea
Jan	1993	: Manufacturers designated for joint development with Qualcomm and ETRI
Mar	1993	: Korean CDMA Systems (CMS)-1 high level design (HLD) started
Aug	1993	: CMS-1 low level design (LLD) started
Nov	1993	: RTS installed and field tested in Seoul
Dec	1993	: CMS-1 hardware implemented and installed for integration
Apr	1994	: CMS-1 software installed and the first successful call made
Jun	1994	: CDMA mobile systems (CMS) -2 implemented and the first successful call made
Sep	1994	: CMS V 2.2. equipped with basic functions of IS-95 developed and transferred to designated manufacturers (DMs)
Nov	1994	: CMS V 2.3 equipped with more functions (handoff, frame staggering, etc.) developed and transferred to DMs
Jan	1995	: CMS-2 commercial field test started in Seoul
Jun	1995	: CMS-2 commercial field test completed
Oct	1995	: Commercial systems deployed and tested in Seoul
Jan	1996	: Commercial service deployed in Incheon by SK Telecom
Apr	1996	: Commercial service began in Seoul, Taejon and connecting highways by Korea SK Telecom and Shinsegi Telecom

Source: Asian Technology Information Program (1998)

Development history of the project was spread over a period of 9 years beginning 1989 (Table 17). The main difference between this one and the previous R&D project was that this was a proprietary technology originally developed and owned by the US telecom manufacturer, Qualcomm. So the project was conceived of as one of joint development.

Organisation and funding[15] : Like the previous R&D project ETRI was the main institution involved in the project together with the foreign partner, Qualcomm. Four domestic manufacturers, namely Hyundai Electronics Industries, L.G Information and Communications, Samsung Electronics., and Maxon Electronics joined the project to develop a commercial CDMA system with a target date for commercial service of early 1996. The key CDMA components are three application specific integrated circuit (ASIC) chips-a cell site modem chip, a mobile station modem chip and a baseband analog chip. These have been supplied by Qualcomm, and delays in delivery and technical hitches were present with increasing regularity. But ETRI and Korean manufacturers have been developing their own versions. The Korean government is now in the midst of developing the International Mobile Telecommunications-2000 (IMT-2000)[16] or third generation mobile

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15 In working out the ideas contained in this subsection I have relied on ICA for Korea IT (2004), Asian Technology Information Program (1998) and on interviews at the ERI during February 2004

16 International Mobile Telecommunications-2000 (IMT-2000) is the global standard for third generation (3G) wireless communications, defined by a set of interdependent ITU Recommendations. IMT-2000 provides a framework for worldwide wireless access by linking the diverse systems of terrestrial and/or satellite based networks. It will exploit the potential synergy between digital mobile telecommunications technologies and systems for fixed and mobile wireless access systems.

technology: 200 professional engineers are working towards the enhancement of IMT-2000. In short ETRI was able to keep pace with changes in technology and move to the next frontier (Table 18).

Table 18: Network evolution in CDMA technology in Korea, 1996-2003

Technology →	CDMA	CDMA	CDMA	W-CDMA
Vintage / Date of introduction →	CDMA IS-95A/B (2G) January 1996 IS-95 A August 1999 is-95B	CDMA 2000 1x (2.5G) October 2000	1X EV-DO (3G) February 2002	1x EV-DO / W-CDMA (3G) December 2003
Maximum speed →	95A: 14.4 Kbps 95B: 64 Kbps	153.6 Kbps	2.4 Mbps	R 99: 384 Kbps R4: 2 Mbps R5: 10 Mbps

Source: Field research notes

The total cost of the CDMA project over the entire period is estimated to be US $ 65 billion. Samsung alone has spent more than $200 million on the project, which involved 1,200 researchers. Part of the financing came from service operators, who had to donate a percentage of their revenues to telecom research. Another part came directly and indirectly from customers, who had to pay a special tax of around $50 on signing up, up to $1,000 for a handset, a $250 deposit and a $100 activation fee. Thus the project is a unique case of even the ultimate consumers financing the creation of a new technology.

Economic effects: As seen earlier in Table 9 the CDMA system technology had the largest market creation effect. There are two major benefits to the Korean economy. First of all Korea managed to acquire both innovation and manufacturing capabilities in not just CDMA technology but also in GSM as well. It has now as a result become one of the leading manufacturers of both mobile handsets and base stations. Two Korean companies, namely Samsung and LG together account for about 15 per cent of the market share (Table 19). Thus it has effectively created a large and growing new industry with a value added creation of 92 trillion Korean Won and which provides employment to about 2.2 million people.

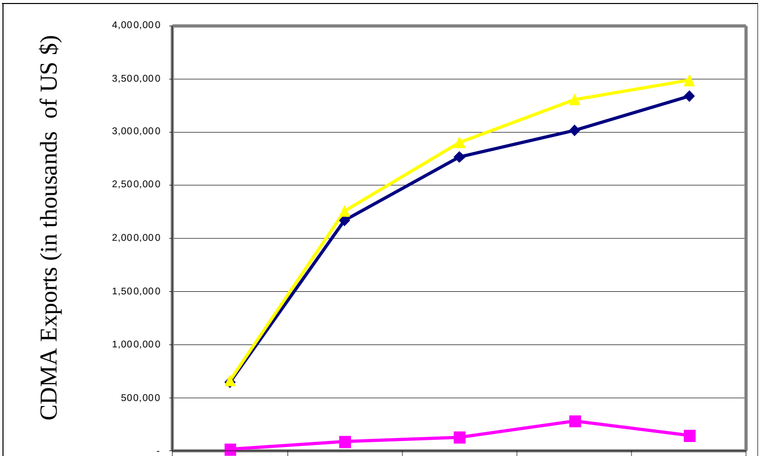
Table 19: World market shares in mobile handsets
(Based on annual shipment in numbers, 2003)

Rank	Manufacturer	Global Sales (2003)	World Market Share (%)
1	Nokia	179339210	33.6
2	Motorola	75439176	14.1
3	Samsung	53004233	9.9
4	Siemens	45344920	8.5
5	LG	27496720	5.2
	Other	52732263	28.6
	Total	533356522	100

Source: International Data Corporation cited in ICA for Korea IT (2004), p. 20

A second important contribution of CDMA technology is the increasing exports of handsets and systems (Figure 9).

It was seen earlier that the CDMA technology was jointly developed by ETRI and Qualcomm. As part of the agreement the manufacturers had to pay a royalty of 5.25 percent based on the total handset price excluding packing and batteries (instead of the chip and related software prices). Over time with the increase in the price of newer



	1998	1999	2000	2001	2002
Handset	646,031	2,170,863	2,767,997	3,015,402	3,336,956
System	16363	90896	133000	287861	151187
Total CDMA exports	662,394	2,261,759	2,900,997	3,303,263	3,488,143

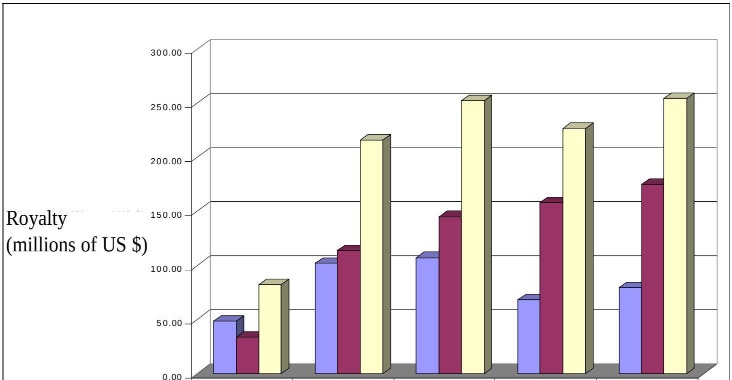
Figure 9: Exports of CDMA handsets and systems from Korea, 1988-2003

Source: Un published data from Ministry of Information and Communication.

vintages of handsets (like the camera phones for instance) this amount of royalty to be paid to Qualcomm is imposing a major burden on the manufacturers. Based on the value of CDMA handset production and exports and applying a rate of 5.25 per cent, I have estimated the amount of royalty that is being paid by Korean manufacturers to Qualcomm and this is presented in Figure 10.

VI. Determinants of innovation capability

From our discussion of the two cases of innovation capability it is abundantly clear that the main determinant of this capability is the strong policy support provided by the Korean government to ETRI and the



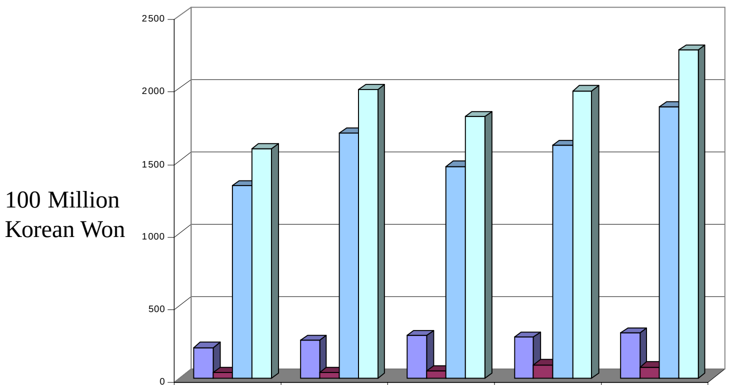
	1998	1999	2000	2001	2002
Domestic sales	48.41	101.92	107.23	68.45	79.73
Exports	33.92	114.13	145.32	158.31	175.19
Total Royalty	82.33	216.04	252.54	226.76	254.92

Figure 10: Estimated royalty payments by Korean manufacturers to Qualcomm, 1998-2002

Source: Computed from data on domestic sales and exports from ICA for Korea IT (2004)

manufacturers. It is this strategic and pro active role played by the government that is the main determinant. In order to accomplish this state has provided financial incentives for the creation of new technology and then has used public technology procurement as an instrument to assure a ready market for the generated technology. Finally the availability of adequate quantity of extremely well trained scientists and engineers is still another important determinant. I discuss these three issues separately.

Financial incentives for technology creation: One of the main components of Korea's innovation system is the public laboratory, ETRI. As seen earlier ETRI's budget largely comes from the Korean government in terms of research grants. In addition the Ministry of Information and Communication maintains three separate research grant schemes and the disbursals under these three have been continually increasing. See Figure 11.



	1996	1997	1998	1999	2000
ITDP	213.1	262.5	295.9	284	315
NATDSP	40.7	40.9	50.2	94	76
ATDP	1330.1	1692.7	1462.4	1607	1874.3
Total	1583.9	1996.1	1808.5	1985	2265.3

Figure 11: Financial incentives for domestic technology creation in telecommunications industry in Korea, 1996-2000

Source: Ministry of Information and Communication.

In addition fiscal incentives are available to private sector enterprises in the form of R&D tax credits etc.

Public technology procurement: This is yet another instrument that has been very successfully by a number of both developed and developing countries as well to promote their respective high tech industries. Korea too has used this especially during the development of TDX fixed telephone equipments. Prior to the financial crisis 1997, Korea was one of the fastest growing telecommunications markets in Asia. However, Korea has always been a difficult market for foreign companies to penetrate. Historically, the Korean government has protected and fostered the growth of the Korean telecommunications industry through strict regulation of equipment type approval procedures, the setting of standards that are unique to Korea, implicit and explicit "buy local" policies. The United States has had a long history of telecommunications market access problems in Korea, and the U.S. Government has initiated several rounds of negotiation with Korea, resulting in a series of telecommunications market access agreements over the past 10 years. The exchange of correspondence between Korean US diplomats refers to this public technology procurement strategy followed by the Korean government. See Box 1.

Box 1: Existence of public technology procurement in telecommunications equipment

April, 1996

The Honorable Michael Kantor, United States Trade Representative

Executive Office of the President, 600 17th Street, N.W., Washington, D. C. 20506

Dear Ambassador Kantor:

I refer to the recent bilateral consultations between the Governments of the Republic of Korea and the United States regarding telecommunications issues. Pursuant to these consultations. the Korean Government is pleased to reaffirm its commitment to comply with the 1990 and 1992 Understandings on Telecommunications (the "ROUs").

In addition to the commitments in the ROUs, the Korean Government will ensure that, in accordance with Korea's commitments under the agreements of the World Trade Organization (the "WTO"), U.S. firms are accorded non-discriminatory access to the Korean telecommunications market.

I. Korea Telecom's Procurement

A. The Korean Government confirms that:

(1) the Korean Government will not require or encourage Korea Telecom to offer preferential treatment to domestically-produced

telecommunications network equipment or commodity products in its procurement process;

(2) the Korean Government will continue to ensure that Korea Telecom extends equal treatment to domestic and U.S. suppliers in Korea Telecom's procurement process, including the future procurement of equipment involving advanced technologies, such as Asynchronous Transfer Mode technology. The Korean Government will further ensure that Korea Telecom does not purposely delay its procurement in order to disadvantage U.S. suppliers; and

(3) the Korean Government will not require or encourage Korea Telecom to obtain a transfer of technology as a condition for awarding a procurement contract for telecommunications network equipment or commodity products through transfer either directly to Korea Telecom or to Korea Telecom's domestic suppliers.

B. The Korean Government further confirms that Korea Telecom's procurement regulations will:

(1) provide adequate protection for the proprietary information disclosed by its suppliers, which either constitutes a trade secret or is otherwise subject to an intellectual property right; and

(2) require suppliers not to infringe on a patent, trademark or any other type of intellectual property right held by a third party in Korea, in fulfilling their contracts with Korea Telecom.

C. Any violation by a supplier of Korea Telecom of a third party's trade secrets or intellectual property rights is actionable under the relevant public law in Korea, including the Unfair Competition Prevention Act.

D. The Korean Government will ensure that, with respect to the equipment covered by Article XVII of the 1992 ROU, Korea Telecom:

(1) consistent with Article VI of the WTO Agreement on Government Procurement, does not prepare, adopt or apply technical specifications with a view to, or with the effect of, creating unnecessary obstacles to international trade; and

(2) consistent with Article VI of the WTO Agreement on Government Procurement, prescribes technical specifications, where appropriate, (i) in terms of performance rather than design or descriptive characteristics; and (ii) based on international standards, where such exist, otherwise on national technical regulations or recognized national standards.

E. The Korean Government will further ensure that Korea Telecom will not require suppliers to submit proprietary technical information (including specifications and/or schematic diagrams) of the telecommunications network equipment and commodity products to be purchased, except to the extent that such information is necessary for Korea Telecom's determination of the supplier's qualification and/or its operation and maintenance of the equipment and products.

II. Approval of Telecommunications Equipment

A. The Korean Government notes that a violation of the type approval regulations by a Korean Government official is punishable under the relevant public law in Korea, including the Korean National Civil Servant Act. The type approval regulations provide for, among other things, protection of the confidential information submitted by type approval applicants.

B. The Korean Government will carefully monitor its type approval process to ensure compliance with the relevant provisions of the 1992 ROU, particularly the provisions regarding documentation requirements for type approval applications. In this connection, the Korean Government will issue a directive to call to the attention of its type approval officials the importance of Korea's compliance with the provisions of 1992 ROU.

C. The Korean Government would like to call the attention of the U.S. Government to the provisions of Paragraph XVI.G. of the 1992 ROU regarding mutual recognition of equipment approval. In this regard, the Korean Government confirms its continuing interest in resuming discussions with the U.S. Government concerning this subject as promptly as possible. It is the Korean Government's belief that a mutual recognition arrangement will serve to significantly enhance each side's access to the other's equipment market.

I would like to inform you that the Korean Government will continue to be amenable to engaging in discussions with the U.S. Government concerning issues arising under the implementation of the ROUs.

I hope that the foregoing clarification is helpful in your understanding of Korean telecommunications policy.

Sincerely,

Ambassador Kun Woo Park, Embassy of the Republic of Korea

Washington,

Source: http://170.110.214.18/tcc/data/commerce_html/TCC_2/KoreaTelecommunicationsMarket.html (accessed on January 28 2005)

However in the case of CDMA technology, there was no necessity to use public technology procurement as the handsets were affordable to individual customers. The emphasis placed by the government on informatisation of the Korean economy is another additional factor that provided a ready or assured market for this new technology.

Human resources development: Given the strong emphasis given by the Korean state the country always had a copious supply of extremely well trained engineers and scientists. The density of R&D personnel in the country has actually increased from 64 per 10, 000 labour force in 1990 to about 108 in 2001 (Korea Industrial Technology Association, 2003). In fact it was seen earlier that the number of researchers in ETRI has actually shown an increase

VII. Conclusions

In this study we were primarily concerned with the innovation capability of the telecommunications equipment industry in Korea. Our analysis shows that despite liberalisation of telecom services and the opening up of the Korean market to foreign manufacturing especially after the Korean financial crisis of 1997, the innovation capability is very much in tact although it may have shifted from the public laboratory to the private sector manufacturing forms. The best way to appreciate the Korean case is to compare it with two other developing countries[17], namely Brazil and India which too have followed the similar strategy of establishing a public laboratory and then transferring the generate technology to domestic manufacturing firms. The comparison is made on three indicators, namely (i) Relative areas of technological strength (Table 20); (ii) instruments of state support (Table 21); and (iii) likely future scenario (Table 22).

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17 Further details of this comparison and indeed with China too can be found in Mani (2006, *forthcoming*)

Table 20 : Relative areas of technological strength of the Brazilian, Indian and Korean telecommunications innovation system

	Brazil	India	Korea
Main areas of technological strength	• Family of digital switching equipments • New Generation Network Switches • Optical Networking Products • Business Support and Operating Systems: Telecom Software	• Family of digital switching equipments especially Rural Automatic exchanges • Jump started the telecom manufacturing industry • Jump started the telecom software industry • Paved the way for the R&D outsourcing industry to take share • Wireless in Local Loop access technologies cor DECT	• Family of digital switching systems especially Rural Automatic switches • New Generation Network Switches • ATM Switching systems • Strong integrative and working relationship with local manufacturing firms and hence a better appreciated of demand • Strong capability in mobile communications technology- CDMA (both Switching Centres and hand sets
Patenting and exports	109 patents were granted within Brazil and 50 were granted abroad No major exports	Patenting record is not known. But considerable exports of smaller capacity exchanges to nearly 22 developing countries	Strong patenting record. A total of 10, 769 domestic patents and 2469 international patents since 1976 Strong exports of both circuit switches and mobile handsets

Source: Own compilation based on Mani (2003 and 2004, 2006)

Table 21: Instruments of state support for innovation capability in Brazil, Korea and India

Brazil	India	Korea
• Public technology procurement (Pre 1998) • Resolution No.155 of 1999 which continues to assure a market for prducts based on Brazilian technology • Research grants in the form of FUNTTEL • Tax incentives for R & D (Law 10176 of 11/01/2001)	• Public technology procurement (modified) • Parliamentary grants (nut now questions are being raised whether to continue to support)	• Public technology procurement • Parliamentary grants • Research grants • Tax incentives

Source: Own compilation based on Mani (2003, 2004, 2006)

Table 22: Assessment about future scenario of the Domestic innovation system for telecommunications in Brazil, Korea and India

Brazil	India	Korea
Learning to adjust to the external environment characterised by increased from MNCs and freer communi-cations is going to the be the major drawback.	*Struggling to exist*. No clear government policies despite being very competent in coping with MNC competition and freer imports.	*Marching forward* with very strong design and manufacturing capabilities in mobile communication technology, although the resrucuring since 1998 did affect it adversely. The changed policy forced in to be short-term in its research focus. However the most recent restructuring efforts have placed it once again on sound footing.

Source: Own compilation based on Mani (2003 and 2004)

Thus it is clear from our foregoing analysis that with clear innovation capability in both fixed and mobile telecommunications technology, Korea's innovation system has been marching forward. Although the private sector manufacturing enterprises have emerged as the most important component of the innovation system, their activities are encouraged or strongly supported by well articulated innovation policy instruments of the state.

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Annexure 1

Service		Service coverage	No of providers	Service provider
Local telephone		Nationwide	2	KT, Hanaro Telecom
Value-added service		Nationwide	2	Dacom, Onse Telecom
Long-distance telephone		Nationwide	3	KT, Dacom, Onse Telecom
Value-added service		Nationwide	1	Hanaro Telecom
International telephone		Nationwide	3	KT, Dacom, Onse Telecom
Value-added service		Nationwide	1	Hanaro Telecom
Telecommunication circuit lease		Domestic International	7	KT, Dacom, G&G Networks, Dreamline, Hanaro Telecom Thrunet, Space Broadband
		Domestic	1	PowerComm
		Long distance international	3	SK Telecom, Hansol iGlobe, Onse Telecom
		International	4	Dacom Crossing, Seoul International Telephone, Korea Level-3 Communications, Samsung Networks
Services provided over allocated frequencies	Mobile telephone	Nationwide	1	SK Telecom (18.44 million)
	Personal Communication service	Nationwide	2	LG Telecom (11.29 million), KT Freetel (5.27 million)
	Global Mobile PCS by Satellite (GMPCS)	Nationwide	2	Dacom, Korea ORBComm

cont'd......

	Service	Service coverage	No of providers	Service provider
Services provided over allocated frequencies	Trunked radio system (TRS)	Regional	5	Seoul TRS (Metropolital Area), KB Telecom (Busan, Gyeongnam), Dagu TRS (Daegu, Gyeongbuk),Power Tel TRS (Gangwon), Jeju TRS (Jeju)
	Wireless Data Communication	Nationwide	3	Air Media, In Tech Telecom, Hanse Telecom
	Radio Paging	Nationwide	1	InTech Telecom
		Regional Areas	4	SeoulMobile Communications (Metropolitan Area), Eysel's Vision (Busan, Gyeongnam), Selim iTEch (Daegu, Gyeongbuk)
	Very high-sped wireless internet	Nationwide	1	Dacom
	IMT-2000	Nationwide	3	KT iComm, SKIMT, LGTelecom

Source: Ministry of Information and Communication (2002)

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